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## Modeling a better burn to boost engine performance

*Engine modeling system simulates a modern 4-valve combustion engine so designers can study how successfully fuel mixes with gases to produce power.*

By David Carrington and Jiajia Waters

In the United States alone, more than 250 million vehicles rely on the tried-and-true internal combustion engine. However, there's always room for improvement, particularly when it comes to better engine performance. With gasoline and diesel becoming more expensive and alternative fuels still experimental, vehicle manufacturers around the world are investing time and effort studying how to improve these familiar motors.

Engine designers are particularly interested in turbulence—the swirling, violent confusion that results from mixing fuel with gases—when fuel burns. By better understanding and thus better predicting the effects of turbulence on the energy efficiency of an engine, researchers hope to better predict and thus manipulate fluid dynamics to improve engine performance.

To study combustion and help improve engine performance, scientists in the Theoretical Division's Fluid Dynamics and Solid Mechanics group at Los Alamos National Laboratory have developed a new software package known as FEARCE. Short for Fast, Easy, Accurate and Robust Continuum Engineering, FEARCE lets engine designers peer into the violent storm of turbulence inside the engine from the comfort of their desktop computer screen or on a much faster supercomputer.

In a car engine, for instance, combustion is a chemical process that releases energy from a fuel and air mixture. This energy drives the engine's pistons. They rotate a crankshaft, which in turn rotates the tires. But what exactly happens at the moment of combustion?

To find out, some engine designers have built see-through engines so they can watch combustion using mockup engine components fabricated from the latest materials. However, even these customized engines and high-speed cameras cannot really capture the essence of combustion. Each combustion stroke lasts only a fraction of a second, the environment is simply much too hot to accurately measure, and the physics and chemistry of the fluids and the gases is bewildering. Still, slowed-down video of combustion in see-through engines is a sight to see. At the moment of combustion, the landscape inside the engine looks like the inside of a volcano, but with the different shades of red ebbing and flowing at the blink of an eye.

To minimize costs, today's engine designers use the latest modeling software in developing better components for engines to improve how fuel and gases are mixed, but these programs have limitations, too. So the only real way to test how experimental components might improve mixing is to build an experimental engine. After a while, fabricating and further modifying the many physical components to evaluate their interactions can become a very time-consuming and expensive affair.

Enter FEARCE: This new software package can predict complex turbulent flows in combustion engines. Such prediction can help designers improve fuel efficiency and reduce emissions in such engines. Compared to previous simulation software, FEARCE applies an innovative numerical method that created models of turbulence based on rigorously evaluated physics. Because the models are true to the physics, designers and engineers can simulate more accurately the turbulence and mixing inside an engine, showing sprays and an engine's moving parts, such as the valves or pistons. This work was funded by the Department of Energy's Energy Efficiency and Renewable Energy Vehicle Technology Office.

Using FEARCE, designers and engineers can better understand the nature of turbulence and how it affects the efficiency of fuel mixing with gases to create optimum energy, which translates to more efficient vehicle power. FEARCE can also model new engine components and run simulations that show how such new components influence and perhaps improve the mixing process, thus changing the turbulence inside an engine so that it generates more power with less fuel while producing fewer pollutants into the air. Cost savings in engine design come from using the software to develop an optimum design that only needs to be physically built once.

Some of today's vehicles now achieve gas mileages as high as 50 miles per gallon. With FEARCE's help, it may be possible to improve engine performance even more, so such engines use less fuel to run, thus improving vehicle gas mileage, perhaps to levels that could save more than 4 million barrels of oil per day, according to Robert Carling, director of the Transportation Energy Center at Sandia National Laboratories. Carling's article published by the *Washington Post* on October 7, 2011, states that in the United States alone, improving efficiency could save drivers upwards of \$400 million every day—for each American, that could mean a healthier wallet. Moreover, better-performing engines could also significantly decrease vehicle greenhouse emissions and other pollutants.

But FEARCE simulates more than just car engines. The software can model any motor, from aircraft engines to turbines to even your everyday lawnmower or go kart. When it comes to improving engine performance, it just doesn't get any more FEARCE.



*David Carrington (right) and Jiajia Waters are scientists studying turbulent reactive flow and computational mathematics in the Fluid Dynamics and Solid Mechanics group at Los Alamos National Laboratory. The duo's invention FEARCE recently was named a finalist in the R&D 100 competition, the "Oscars of Innovation."*

